ORIGINAL ARTICLE

# Sustainability of Underutilized Local Crop Through Product Development of Malaysia Purple Sweet Potato Cracker

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## ABSTRACT

**Introduction:** Purple sweet potato is one of the most underutilized commercial local crops in Malaysia despite its various health benefits. Thus, purple sweet potato cracker has been developed to promote the local crop as a novelty food for Malaysians that is low in fat and high in fiber. Furthermore, the addition of Chia Seeds to the formulation is intended to increase its nutritional values and sensory properties. **Methods:** The crackers were evaluated for proximate composition and sensory characteristics, taste, aroma, texture, color, appearance, and acceptance. **Results:** This study found that a total of 8.4 to 8.7 g of protein and 68.5 to 68.9 g of carbohydrate were contained in 100 g of cracker samples. In addition, 11.1 to 11.4 g of crude fiber per 100g of sample was also reported. Interestingly, the amount was more than the recommended fiber intake by Codex Alimentarius on Dietary Fiber in 2009, which must be more than 3 g per 100 g. Besides that, the ratio of purple sweet potato and other ingredients used in this study were 50:100, 52:100, 54:100, 56:100, and 58:100. The results of the Hedonic sensory analysis showed that the formulation with a ratio of 54:100 was the most preferred formulation by the trained panelists in terms of aroma, color, and appearance. **Conclusion:** The created Malaysian Purple Sweet Potato Cracker with a high fiber content has the potential to be promoted in Malaysia as one of the healthiest crackers, perhaps increasing consumption of the underutilized purple sweet potato.
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## INTRODUCTION

Sweet potato or scientifically known as *Ipomoea batatas L.* is one of the main sources of carbohydrates. Sweet potatoes have a few colors and varieties. Orange-fleshed, yellow-fleshed, and purple-fleshed are examples of these potatoes and were the most common varieties of this crop. Sweet potato is one of the healthful foods recommended by the United Nations' Food and Agriculture Organization (FAO) (2) due to the presence of β-carotene, anthocyanins (32, 34), vitamins (B1, B2, C, and E) (33), and minerals (Ca, Mg, K, and Zn) (3,4). Many scholars have suggested that the sweet potato's specific composition is significant to its anti-oxidative (4), hepatoprotective anti-inflammatory (6), anti-tumor, anti-diabetic, anti-microbial(5), anti-obesity(1), and anti-aging properties (7).

The use of sweet potato roots, leaves, and stems is becoming increasingly popular as ingredients in food formulation among scholars because its nutritional profile suggests benefits to human health (21). Thus, it could increase the consumption of sweet potatoes especially the purple type for consumption purposes.

Many countries such as China Vietnam and India produce sweet potato as their main crops (2) and in Malaysia, sweet potatoes can be considered as cash crops with 24.93% planted area (10). In 2017, a total of 4,634.79 metric tonnes (mt) sweet potatoes were produced (10), with its highest production area in Sepang, Selangor, Malaysia. Generally, sweet potatoes are a warm-weather crop, and they require warm soil. Besides that, it also needs humid weather for at least 4 to 5 months of the year. The best temperature range

for sweet potato production is 22 degrees Celsius to 20 degrees Celsius. Furthermore, this plant may be grown in both tropical and subtropical climates, and sunny days are ideal for tuber development (10).

Nevertheless, a study had suggested that the demand and consumption of the local sweet potatoes, especially the purple sweet potato, by Malaysian consumers have been alarmingly low (35). In the culinary sector, all the sweet potato mainly the purple sweet potato is not considered as the major ingredient in most traditional Malaysian dishes including Malay traditional food. The use of sweet potato in Malay traditional food preparation is mostly limited to dessert making. Desserts such as *che mek molek* (Kelantan delicacies) and *bubur keledek* are examples of Malay traditional food that are made of orange sweet potato but not the purple variety. Findings have suggested that most Malaysians rarely enjoy eating boiled sweet potato roots, especially the purple sweet potato. Furthermore, research has also found that the majority of children, adolescents, and young adults do not prefer to eat purple sweet potato in general (35). Therefore, Malaysian sweet potatoes, particularly the purple sweet potato remain an underutilized crop.

It is a common phenomenon to see most of the Malaysian purple sweet potato left unsold at the supermarket as compared to other local vegetables. Due to this, the retail price of this crop has been fluctuated, which is evident in the increased price in 2016 and decreased price in 2017. In 2016, the farm price was reportedly RM 1640 per ton, while the retail and wholesale prices were reportedly RM 2780 and RM 4030 per ton, respectively. Nevertheless, the prices per ton of sweet potatoes decreased in 2017 to a farm price of RM 1660 per ton, the wholesale price of RM 2600 per ton, and the retail price of RM 3850 per ton (10). The trend demonstrates that there was a decrease in the production of sweet potatoes and prices, accordingly. The trend also indicates the low demand and consumption of sweet potatoes by Malaysian consumers.

Recently, several manufacturers have reportedly produced snacks made of sweet potatoes as an addition to their snack varieties without the intention to promote its health benefits to the population. The high nutritional values of Malaysian purple sweet potato are still overlooked. On the other hand, Wang, Nie and Zhu (5) suggested that the use of underutilized local sweet potatoes should be further diversified as the crop is still underrepresented in the commercial market. In addition, Zhu and Sun (9) and, Zhu and Wang (11) asserted that sweet potatoes can be further developed as a sustainable crop for the production of diverse nutritionally enhanced and value-added food products that are beneficial for human health. Therefore, purple sweet potato (PSP) can be developed as a cracker with improved nutritional quality due to its functional properties and health benefits.

Nowadays, the development of healthy snacks from local crops has become one of the main initiatives driven by manufacturers and small-medium entrepreneurs (SME) in line with the growing concern about healthy eating among local consumers. Cracker is one of the most common snack foods consumed by Malaysian consumers due to its convenience, ready-to-eat nature, and long shelf life. Various types of crackers have been introduced to the market, which includes crackers made from the local crop. However, purple sweet potato crackers have rarely been found in the Malaysian market despite their various health benefits. The poor demand for sweet potato crackers may also be driven by the low consumption of raw (fresh tuber) sweet potatoes among Malaysian consumers. It has been a challenge to ensure consumer acceptance of the crackers made from purple sweet potatoes especially among the health-concerned population in the Malaysian market. Therefore, a study on the processes involved in the product development to produce snacks made from this local crop is very important. In this work, the formulation and preparation of crackers made from the Malaysian sweet potato using the optimum combination of basic ingredients with the addition of chia seeds were examined, and the physicochemical characteristics and sensory properties were evaluated by the trained panelists.

## MATERIALS AND METHODS

This research was an experimental study and obtained ethical clearance from the ethical committee of the Universiti Teknologi MARA (UiTM) and Faculty of Health Sciences, UiTM (approval number REC/12/2020 (MR/456). The study was conducted at the Food Analysis Laboratory, Faculty of Hotel and Tourism Management, and Faculty of Health Sciences, Universiti Teknologi MARA (UiTM) Puncak Alam, Selangor.

### Formulation Development of Cracker from Purple Sweet Potato

The basic formulation of cracker from purple sweet potato was developed to get an optimum percentage of each ingredient in the mixture. The original formulations of the cracker were prepared according to the method by Gisslen (15) with modification by the researcher. For cracker processing purposes, purple sweet potato was bought from the local market at Jalan Kebun, Seksyen 38 Shah Alam, Selangor Malaysia while other ingredients, such as strong flour, milk, unsalted butter, heavy cream, salt, sugar, and chia seed were bought from Tesco Puncak Alam, Kuala Selangor.

### Preparation of Purple Sweet Potato Cracker

The purple sweet potatoes were firstly washed, followed by peeling off the skin and boiling until cooked. The fleshes were mashed using the masher with its weight measured according to the standard formulation. All ingredients were combined and the dough was rested

for 10 minutes in the chiller. To shape the cracker, the dough was flattened using a dough sheeter and cut into rectangular ( 4 cm in length and 4 cm in width). Next, the crackers were baked in the oven for 15 minutes at 170 ℃ in a preheated oven. Once cooked, the crackers were cooled for 30 minutes before packing in sealed plastics and stored in an air-tight container at room temperature for further analysis.

**Proximate Analysis**

The proximate analysis was carried out according to the Association Of Official Analytical Collaboration, AOAC (1995) to determine the carbohydrate, protein, and crude fiber contents.

**Sensory analysis by trained panelists**

Sensory analysis by the trained panelists was carried out for the five new formulations of PSP crackers incorporated with different amounts of purple sweet potato flesh of overall ingredients, 50:100, 52:100, 54:100, 56:100, and 58:100. Cracker samples were subjected to sensory evaluation by seven trained panelists who were among staff and lecturers of the Faculty of Hotel and Tourism Management with experience in food testing. Seven trained panelists aged between 35 and 55 years old participated in this session. Before the evaluation started, instructions for sensory assessments were carefully explained to the panelists. The panelists had no prior information about the coded test products.

Panelists were asked to evaluate the taste, color, aroma, texture, and overall acceptability of the products. All of the five sensory attributes were measured using the nine-point hedonic scale s based on Sittisak, Fuengkajornfung, Sanprom and Weenuttranon (16) for sensory evaluation. The scale of values varied from "extremely like" to "extremely dislike" that corresponded with the highest to lowest scores of "9" and "1", respectively. The order of presentation was balanced and randomized to eliminate contrast and potential bias effects. After evaluating the cracker samples, the panelists were interviewed by the researcher regarding the overall acceptability of the crackers. The interview sessions took around 5 to 10 minutes. All data was digitally recorded.

**Statistical Analysis**

All data were analyzed according to two different categories. Firstly, the sensory hedonic scores based on evaluation by the seven trained panelists were analyzed using IBM SPSS Statistic (Version 27). Analysis of variance (ANOVA) was performed and the differences were analyzed with Tukey test using a confidence level of 95% (12,13). Furthermore, the feedback from the interview sessions were analyzed using thematic analysis using Atlas. ti (14).

## RESULT

**Development of Cracker Formulation**

The basic formulation for professional baking developed by Gisslen (15) was used with modification by the researcher, who added chia seeds to enhance the nutritional value. Food reformulation by modifying certain compositions or reducing some of the ingredients is vital for food production. The five formulations used in cracker preparation are shown in Table I.

Table I shows five new formulations with the addition of chia seeds, unsalted butter, salt, sugar, milk, and cream. Different amounts of boiled purple sweet potato flesh (5% to 25%) were used to reach the acceptable level f sensory evaluation. The P1, P2, P3, P4, and P5 samples were added with 50%, 52%, 54%, 56%, and 58% of purple sweet potato from total ingredients, respectively. The range of the amount of purple sweet potato to be added into the formulation was determined based on previous studies (16, 9), as well as based on trial and error carried out by the researcher.

**Table I: Percentage of ingredients in five formulations of crackers**

| Ingredient | Formulation (%) | | | | |
|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 |
| Boiled purple sweet potato flesh | 50.0 | 52.0 | 54.0 | 56.0 | 58.0 |
| Strong flour | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| Unsalted butter | 13.5 | 13.0 | 11.0 | 9.0 | 7.0 |
| Salt | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Sugar | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Milk | 2.5 | 2.0 | 2.0 | 2.0 | 2.0 |
| Cream | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Chia seed | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

**Proximate Composition**

Table II displays the compositions of crude fiber, protein, and carbohydrate in the newly developed purple sweet potato crackers.

**Table II: Proximate results of the newly developed PSP crackers**

| Proximate analysis (g/100g) | Newly Developed PSP Cracker |
|---|---|
| Crude Fiber | 60.3 ±0.13 |
| Protein | 8.7±0.05 |
| Carbohydrate | 68.9± 0.54 |

**Crude Fiber**

The purple sweet potato flesh contained a high content of fibers. The content of crude fibers in the newly developed PSP cracker was 60.3 g/100 g. Notably, the recommended dietary fiber consumption per day by US Department of Health and Human and US Department of Agriculture (2015) is 30 g for a diet to be considered healthy. In this study, the amount of dietary fiber in the newly developed PSP cracker exceeded the recommended amount indicating its high nutritional value. This finding is similar to the previous studies which suggested that vegetables and fruits are excellent sources of fiber that could enhance the functionality of food products (6,12,13, 18, 27). It is deduced that the newly developed PSP cracker contained high dietary fiber due to the presence of purple sweet potato root. Therefore, this PSP cracker could be one of the daily healthy snacks for human consumption.

**Protein**

This study reported the presence of 8.7 g/100 g protein content in the newly developed PSP cracker. United States Department of Agriculture National Nutrient Database (2015) reported that the amount of protein in sweet potato is around 1.57 g. It is deduced that the high protein content in PSP crackers in this study was due to the combination of protein contents in the ingredients namely wheat flour, chia seeds, cream, and milk. Flour, for instance, has different protein contents depending on its variety and it is important to determine the intended use of the flour (19). There are various types of flours with low and high protein contents, which may influence the properties of the final food products. Normally, flours with high protein contents are suitable for crackers production, whereas flours with low protein contents are suitable for making cookies and cakes. Although wheat flour consists of high protein, its use in cracker formulation contributes to the texture and tenderness of the cracker (20). In addition, gluten in the wheat flour was found to improve the functionality of cracker dough during the baking process (28).

**Carbohydrate**

Carbohydrates are important elements as they provide energy and are deemed essential for human growth development. WHO (1990, 2003) has recommended the intake of total carbohydrates from 55% to 75% of total energy. The amount of carbohydrates was determined based on the overall energy need of 10% to 15% from protein and 15% to 30% from fat. In addition, it has also been reported that the recommended glucose intake as part of the carbohydrates by adults is between 110 and 140 g/day. Carbohydrates content in the newly developed PSP cracker was 68.9 g/100 g. A study on nutritional profiles of snack bars from soy and purple sweet potato consumed by pregnant women showed that 38.06 % of carbohydrates content was determined in the formulation incorporated with 70% of purple sweet potato and 30% of soybean (31). Low carbohydrates content in the snack bars might be due to the absence of wheat flour in the formulation as compared to that of PSP crackers in this study, which incorporated wheat flour in combination with purple sweet potato flesh.

**Sensory Attributes Comparison of Purple Sweet Potato Cracker**

Table III compares the attributes of sensory from purple sweet potato crackers produced using the five new formulations as determined by the trained panelists.

The descriptive statistics that look at the means score and standard deviations were applied as presented in Table III. The results represent the ratings for sensory quality and acceptability of the improved PSP crackers by seven trained panelists. All five formulations were coded as P1, P2, P3, P4, and P5, accordingly. To differentiate the scores based on characteristics of crackers, a web radar (9) was illustrated as shown in Fig 1.

**Table III: Hedonic scores of the improved PSP crackers evaluated by the trained panelists**

| Sample | Sensory Attributes | | | | | Overall Liking | Acceptability |
|---|---|---|---|---|---|---|---|
| | Taste/ flavor | Aroma | Texture | Colour | Appearance | | |
| P1 | 4.14±0.69 | 3.85±0.89 | 3.71±1.11 | 4.00±0.81 | 4.28±0.75 | 4.42±0.53 | 4.71±0.48 |
| P2 | 7.71±0.75 | 7.57±0.78 | 7.00±1.00 | 6.42±0.53 | 7.00±0.81 | 7.28±0.75 | 7.14±0.377 |
| P3 | 8.42±0.53 | 8.71±0.48 | 8.57±0.53 | 8.71±0.48 | 8.71±0.48 | 8.42±0.53 | 8.28±0.49 |
| P4 | 6.14±0.69 | 7.14±0.69 | 6.57±1.13 | 6.14±0.89 | 6.42±0.53 | 6.71±0.48 | 6.71±0.48 |
| P5 | 4.14±1.06 | 4.57±0.53 | 4.28±1.11 | 4.42±1.13 | 4.28±1.38 | 4.85±0.69 | 4.57±0.78 |

Values are presented as means ± standard deviation.

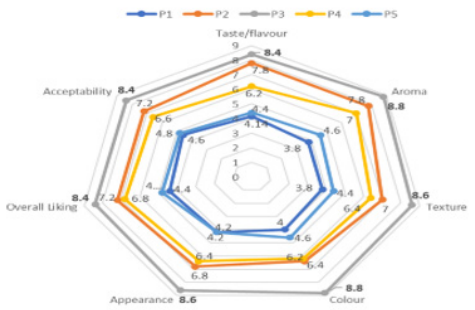


**Fig 1: Mean ratings for sensory attributes of five formulations of PSP crackers as per evaluation by the trained panelists.**

Overall, the results showed that the sample P3 had the highest mean score for all sensory attributes in comparison with other formulations. P3 formulation consisted of a combination of all similar ingredients used in other formulations, with the addition of 54% of boiled PSP flesh. The panelists demonstrated extreme liking toward all the attributes of the P3 sample. The mean sensory scores as per evaluation by the trained panelists for the P3 sample were 8.42±0.53 for taste/flavor, 8.71±0.48 for aroma, 8.57±0.53 for texture, 8.71±0.48 for color, 8.71±0.48 for appearance, 8.42±0.53 for overall liking, and 8.28±0.49 for acceptability. Comparing the results of all samples, the majority of the trained panelists demonstrated moderate liking toward the P2 sample, with mean scores of 7.71±0.75 for taste/flavor, 7.57±0.78 for aroma, 7.00±1.00 for texture, 6.42±0.53 for color, 7.00±0.81 for appearance, 7.28±0.75 for overall liking, and 7.14±0.377 for acceptability.

The panelists also demonstrated moderate liking toward the P4 sample with mean scores of 6.14±0.69 for taste/flavor, 6.57±1.13 for texture, 6.14±0.89 for color, 6.42±0.53 for appearance, 6.71±0.48 for overall liking, and 6.71±0.48 for acceptability. Nevertheless, the panelists moderately liked the aroma of the P4 sample with a mean score of 7.14±0.69. The addition of 10% strong flour on the other hand was found to reduce the sensory scores of the P2 sample as compared with that of the P3 sample. It is apparent based on the figures presented that most of the attributes of the P1 and P5 samples were slightly disliked by the panelists. Notably, the panelists moderately disliked the aroma (M=3.8) and texture (M=3.8) of the P1 sample.

As the opinion of experts is important for product formulation development and verification, the next discussion, therefore, focuses on the results generated based on the interview sessions with the trained panelists. The answers in thematic coding based on the interview sessions with the trained panelists are presented in Table IV.

**Table IV: Number of responses to the question from the trained panelists**

| No. | Variables | N |
|---|---|---|
| 1. | Has a good taste/flavor | 6 |
| 2. | Good Crunchiness | 7 |
| 3. | Good color | 6 |
| 4. | Value add to the shape | 5 |
| 5. | Nice aroma | 5 |

Based on the table, there are a few examples of the verbatims quoted from the interview session that is related to the verification of the crackers' attributes by the trained panelists. The answers were identified as follows:

### Has a good taste/flavor

It is interesting to reveal that all trained panelists claimed that they have never seen crackers made from purple sweet potato sold in the market. The panelists reported that their first time eating or tasting crackers made from this unique crop was during the conduct of this study. In general, four of the seven trained panelists stated that the improved PSP cracker has a good taste/flavor. This result further supported the finding that the combination of flour and purple sweet potato flesh enhances the sensory quality, including the taste of the product (22). The result was also in line with Zettel and Hitzmam (30) which suggested that the addition of chia seeds adds flavor to food products. The creamy taste was reported in most samples. One of the respondents described the cheesy taste of the PSP cracker, which quoted as follows:

> This PSP cracker has good taste. Its creamy taste makes me feel like eating commercial crackers from the market. I like this new idea and the innovation of this cracker.
>
> (Trained panelist 2, 52 years old)

> I like the taste…even I rarely eat the purple sweet potato, but this cracker is like the other snacks in the market.
>
> (Trained panelist 3, 35 years old)

### Good Texture and Crunchiness

The trained panelists also admitted that the PSP crackers in this study had a good crunchiness (n=7). The results seemed to be consistent with that of other research which found the use of chia seed mucilage gave the best texture, desirable color, and mouthfeel. A previous study demonstrated that any products added with chia seeds were highly acceptable based on the overall quality score obtained from respondents (17).

The incorporation of flour in the formulation resulted in extreme liking of the product by respondents due to its gluten content (20). The reaction between gluten and fat and milk increases the crunchiness of the cracker. Besides, the purple sweet potato flesh itself contributes to the desired textural properties of food products including crackers (21). Few responses from the trained panelists are quoted as follows:

> This sample is very crunchy. The texture is good…I believe you control the baking time accordingly, so that you get this crunchy cracker.
>
> (Trained panelist 1, 46 years old)

> Overall…it's crunchy. The combination of ingredients for this cracker contributes to its good texture. It is difficult to reach the optimum level of this type of crunchiness. With the correct technique, you manage to produce this crunchy cracker from purple sweet potato.
>
> (Trained panelist 6, 37 years old)

**Pleasant color**

Color, according to the trained panelists, increases eye appeal and influences the overall appearance of the cracker. Thus, it also influences the acceptability of the crackers. Panelists in this study reported that the color makes the crackers look pleasant in addition to the nice aroma. Two of the respondents asked the researcher during the interview sessions whether or not there was an addition of coloring in the cracker formulation. The result obtained was consistent with a previous study, which reported that the high-level content of anthocyanins in purple sweet potato gives off the natural color purple (21). The finding also demonstrated the potential consumption of purple sweet potato as a synthetic coloring agent in food products. Some of the trained panelists' verbatims are quoted as follows:

> It has a pleasant color and very eye appeal. Nice color!!
>
> (Trained panelist 1, 46 years old)

> It's a beautiful color. It's quite difficult to get this natural color for a cracker.
>
> (Trained panelist 5, 45 years old)

> Your cracker color is very nice. It is good to have this typeof color from a natural source. It makes the cracker looks more attractive and an eye appeal cracker.
>
> (Trained panelist 7, 41 years old)

**Nice aroma**

Overall, the trained panelists conveyed that the combination of the ingredients in the PSP cracker formulation enhanced the quality of the cracker not only in its texture, color, taste but also in its appearance. The aroma may encourage consumption, particularly among children, and thus, attract more customers to eat this product. Some of the trained panelists' verbatims are quoted as follows:

> The ingredients are a good blend. Its aroma smells nice. We also, can see it from its overall appearance… it has a smooth surface. Even its texture and color..all this because of the ingredients that you used.
>
> (Trained panelist 2, 52 years old)

> To me…this cracker has a good aroma. It smells nice. It's like a creamy cracker…maybe because it's flesh.
>
> (Trained panelist 5, 37 years old)

> It has a nice aroma...very pleasant. Children will love eating this cracker.
>
> (Trained panelist 7, 41 years old)

**Value add to the purple sweet potato**

The consumption of local purple sweet potato flesh as the main ingredient in cracker formulation in this study can be considered as part of innovation when compared to other sweet potatoes such as the orange sweet potato, which is the most consumed by consumers. This cracker, according to the trained panelists, was new to them as it was the first time they tried the crackers made from purple sweet potato. The panelists admitted that they rarely eat purple sweet potato even in the boiled form. Nevertheless, the introduction of this cracker in the market may encourage the panelists and other consumers to eat more of this local crop. The result was consistent with Nurminah and Nainggolan (25) which found that the flesh of purple sweet potato is good for processing food products.

Besides, the panelists also suggested that the addition of chia seeds in the cracker formulation enhances the value of the cracker as people are aware of the health benefits of the chia seeds consumption. This result reflected finding by Da Silva (23) which showed that chia seeds increased food production values as it contains dietary fiber, vitamins, and minerals. The presence of chia seeds can be seen in the appearance of the PSP cracker, which made it easy for the trained panelists to identify the chia seeds added to the cracker. Some of the verbatims quoted are as follows:

> We have our traditional kerepek in the market. But it's different compare to this cracker. This is a new cracker…
> from purple sweet potato. It's one of the values added to our local crop.
>
> (Trained panelist 2, 52 years old)

> I rarely eat purple sweet potato flesh…but I like the orange one. It's quiet sometimes I ate the purple potato. It's good to have this cracker from purple sweet potato. It's new!! Other people will also like to eat this new cracker from purple sweet potato.
>
> (Trained panelist 3, 35 years old)

> It's a new type of cracker. Some people don't like purple sweet potatoes. Even I rarely eat purple sweet potato either in boiled form or another form. It's a new value to this crop.
>
> (Trained panelist 4, 48 years old)

The above verification responses suggested that the improved PSP cracker can potentially be commercialized on a big scale. Overall, the P3 sample was chosen as the best formulation as compared with other formulations. Notably, the five formulations were composed of similar ingredients (strong flour, unsalted butter, salt, sugar, milk, heavy cream, and chia seed), with only the percentage of purple sweet potato content differing. Out of the five formulations, the panelists chose the P3 sample that was incorporated with 54% of boiled purple sweet potato flesh as the best formulation. A previous study has found that wheat flour can be added with at least 20% of potatoes to increase the sensory quality (22).

## DISCUSSION

Purple Sweet potato which is normally categorized as an underutilized crop in Malaysia is one of the crops that contain a lot of nutrients. The benefits to human health can increase the use of this crop among consumers, especially Malaysians. Studies that formulate ingredients from purple sweet potatoes, will be able to make purple sweet potatoes a daily food. For example, the PSP crackers developed in this current study were found to contain various nutritional contents for health benefits and are suitable for daily consumption. Besides that, chia seeds have been used in various formulations of food products. It is a hydrocolloid (30), which is important in food product acceptability. It increases the physical stability and mouthful characteristics. Besides, chia seeds have also been added to various food formulations due to their role as a fat replacer in bakery products (17). Thus, the addition of chia seeds in the formulation may enhance the quality of the overall mouthfeel of the PSP cracker.

A previous study reported the content level of crude fiber in the crackers made from sukun or breadfruit, Artocarpus altilis and sweet powder purple flour and saga seeds or called rosary pea (Adenanthera pavonine) ranged from 3.13% to 6.68% (29) as compared to the newly developed PSP crackers reported in this study. The fiber composition in modified flour is low due to the process that occurred during the production of the flour as compared to that of fresh or cooked vegetables. In the current study, the incorporation of boiled purple sweet potato flesh used in the formulations contributes to the high content of crude fiber in the PSP crackers. On the other hand, the crude fiber content in the orange sweet potato fleshed added to the cookies with edible mushroom was reportedly low, ranging from 1.01–3.68% (24).

According to European Parliament and Council regulations from 2006, food can be labelled as a "source of fibre" if it includes at least 3 g fibre per 100 g of product, whilst "rich or high in fibre" means it has more than 3 g fibre per 100 g of product. Thus, the PSP crackers reported in this study can be considered high-fiber crackers. This particular composition presents a good added value for the commercialization of purple sweet potatoes as one of the healthy food alternatives. This is also in line with the Malaysia Food Act 1983 and Regulations (2014), whereby it is mentioned Food with a total Total Dietary Fiber (TDF) content of more than 6% can be labeled as (1) high in fiber, and food with a TDF level of more than 3% can be labeled as a fiber source.

Therefore, the PSP crackers containing 53% boiled purple sweet potato flesh presented in this study can be considered as high-fiber food. Previously, the orange sweet potato puree has been used in brownies, which contributed to 75% of fiber content found in the brownies—therefore can be considered high-fiber food (26). This PSP cracker could be one of the daily healthy snacks for human consumption as the cracker contained high dietary fiber due to the presence of purple sweet potato root.

Preliminary results finding found that protein contents in crackers ranged from 1.65% to 12.64% were derived from flours of sukun and purple sweet potato flour (29). The amount of protein content in the newly developed PSP crackers reported in this study is considered high, which may be related to the usage of boiled purple sweet potato flesh without the addition of any other composite flours. In contrast, a previous investigation on the effect of guar gum on the qualities of waffles made from purple sweet potato flour reported low protein content (7.67 g/100g (28)) as compared to the PSP crackers reported in this study. As the cooking process, temperature, and time used were different between crackers and waffles, it may influence the protein content in the end products. Protein is very important and useful in human growth, as well as may boost body metabolism.

On the other hand, 65.54 % of carbohydrates were reported in the egg roll from the combination of 40% wheat flour and 60% purple sweet potato flour (25). The carbohydrates contents found in the study were almost close to the carbohydrates content present in the PSP crackers reported in this study. In addition, Kolawale, Akinwande and Ade-Omowaye (24) also reported that they found 62.34 to 67.22% of carbohydrates in their

cookies. Thus, the PSP cracker could be an alternative for carbohydrate snacks as carbohydrates are the primary source of energy, and consuming an adequate amount of them may benefit the digestive system.

Nevertheless, the current reported carbohydrates content in PSP cracker was in line with Sungin (28) who reported that 68.92 g/100g of carbohydrates in the waffle. The carbohydrate value of PSP crackers was also consistent with that of biscuits from orange sweet potato puree and wheat flour, which contained carbohydrates in the range between 62.20% and 68.43% (27).

The overall results of the sensory evaluation revealed that the formulation with a ratio of 54:100 whereby 54% was the boiled PSP flesh and another 46% were the other ingredients (P3 sample) was found suitable in the improved PSP cracker and accepted by the trained panelists. From these five new formulations of PSP crackers, two of the formulations were accepted by the panelists, namely the formulations of P2 with 52% of strong flour and P4 with 56% of boiled PSP flesh. Besides, the overall combination of the ingredients used in PSP crackers has enhanced its sensory quality. The color, aroma, and appearance of the PSP cracker were found to influence the acceptability of PSP crackers among the trained panelists. The taste, crunchiness, and texture of the cracker also contributed to its acceptance by the panelists. The addition of chia seeds and other ingredients like unsalted butter, cream, and milk, contributed to the overall acceptability of the cracker. This current study can also be a reference for researchers to conduct further studies based on this sweet potato on a broader scope, especially from the perspectives of consumers as this study only focuses among the trained panelists' perspectives.

## CONCLUSION

The research on purple sweet potatoes as major ingredients in food formulation is able to benefit the sustainability of this type of sweet potato in Malaysia scope. It may promote this underutilized local crop through the various product development processes. The use of purple sweet potatoes as a basis in the preparation of crackers in this study may contribute a significant impact due to the lack of commercial products related to this sweet potato in the market. In addition to increasing the income of farmers, it is also able to attract consumers to eat this sweet potato. Disclosure of the benefits and nutrients of purple sweet potatoes especially for health needs to be enhanced. Considering that the PSP crackers reported in this study have high fiber content, carbohydrates as well as protein, this food product may as well sell as one of the healthy snack alternatives.

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